

Project Progress

EXECUTIVE SUMMARY

The purpose of the Evolutionary Genomics Focus Group (EvoGenomics) is to coordinate, combine, and enhance research efforts involving evolutionary genomics across the multiple disciplines and institutions represented in the astrobiology community. EvoGenomics is a unique collaboration of astrobiologists combining expertise in molecular evolutionary analysis, organic chemistry and biochemistry, Earth history, and paleontology. The focus group serves as a forum for discussions and collaboration among researchers with similar interests, through workshops, videoconferences, and breakout sessions at annual meetings. New research initiatives and database activities are fostered through focus group activities.

Genomes provide a record of the history of life. Therefore, evolutionary analysis of genomes is fundamental to understanding that history and how life affected the biosphere. This corresponds to Goal 4 of the NASA Astrobiology Roadmap (Earth's early biosphere and its environment). Other relevant goals are Goal 5 (Understand the evolutionary mechanisms and environmental limits of life), Goal 3 (Origins of life), and Goal 7 (Signatures of life).

The current participants of the Evolutionary Genomics Focus Group are Steven A. Benner (University of Florida), Jack D. Farmer (Arizona State University), James R. Garey (University of South Florida), Eric A. Gaucher (University of Florida), J. Peter Gogarten (University of Connecticut), S. Blair Hedges (Penn State University), Christopher H. House (Penn State University), David K. Jacobs (University of California, Los Angeles), Joseph L. Kirschvink (Caltech), Sudhir Kumar (Arizona State University), James A. Lake (University of California, Los Angeles), Charles R. Marshall (Harvard University), Monica Riley (Marine Biological Laboratory), Lynn J. Rothschild (Ames Research Center), Bruce N. Runnegar (University of California, Los Angeles), and Mitchell L. Sogin (Marine Biological Laboratory).

Three workshops and symposia were held during the first three years of the focus group. One workshop took place at the University of California, Los Angeles (9–11 March, 2001), hosted by co-chair Lake, and it focused on discussions of animal origins and the influence of Neoproterozoic snowball Earth events and relationship

with the Cambrian Explosion of animal phyla in the fossil record. A focus group symposium (Special Session) was held at the NAI General Meeting, 10–12 February 2003 at Arizona State University, chaired by Lake and Hedges. Speakers included Herve Philippe (University of Montreal), Beverly Green (Vancouver), Lake, Riley, Janet Siefert (Rice University), James Staley (University of Washington), Blair Hedges, and additional presentations were given by graduate students and postdoctoral fellows (Eric Gaucher, Davide Pisani, Jaime Blair, Maria Rivera, and Cody Nash).

Another Evolutionary Genomics Focus Group "special session" was held at the Gordon Research Conference on the Origin of Life at Bates College, Maine (13–18 July, 2003), chaired by Hedges and Lake. In this case, the 19 speakers were split into two sessions on separate days: "Origin and Evolution of Eukaryotes" (Beverly Green, Peter Gogarten, Herve Philippe, Maria Rivera, Jim Lake, Blair Hedges, Leonid Moroz, Lynn Rothschild, Hyman Hartman) and "Tree of Life and Horizontal Gene Transfer" (Joe Kirschvink, Yuri Wolf, Peter Gogarten, Herve Philippe, Richard Greenblatt, Jim Lake, Eugene Koonin, Joshua Rest, Blair Hedges, and Ford Doolittle).

Research by focus group participants, augmented with support from NAI, has led to several discoveries. For example, proteins that existed three billion years ago were "resurrected" in the lab and shown to support a model for the early Earth environment (Gaucher et al., 2003; **Nature** 425:285–288), major divergences within fungi were estimated to have occurred deep in the Precambrian (Heckman et al., 2001; **Science** 293:1129–1133), and a new mechanism for protein synthesis was proposed that suggests how the current RNA/Protein world may have started from an RNA world (Simonson and Lake, 2002; **Nature** 416: 281–285).

The Evolutionary Genomics Focus Group web site (www.evogenomics.org) describes the function of the focus group, participants and contact information, and research undertaken by the participants. Publications of the focus group participants since creation of NAI in 1998 are listed by year, and electronic copies of the papers are linked to the citations. One web page presents links to computational tools. Undergraduate, graduate, and postdoctoral research and educational opportunities are presented on separate pages. Finally, a calendar page lists links to upcoming meetings and events of interest to astrobiologists and participants of the focus group and evolutionary genomics community.

Future workshops will be organized and held over the next three years. The themes of each workshop will be timely and pertain to key issues in evolutionary genomics, with relevance to astrobiology. Examples of some possible themes are: (i) molecular phylogenies and the early history of life, (ii) prokaryote genomes and phylogeny, (iii) molecular evidence for the origin of eukaryotes, (iv) a timescale of Precambrian evolution, (v) evolutionary genomics and the Cambrian explosion, and (vi) horizontal gene transfers in early evolution. Workshop participants will include world leaders in each of the research areas (NAI members and persons not affiliated with NAI). In each case, arrangements will be made with an astrobiology or related journal to publish the proceedings of the workshop.

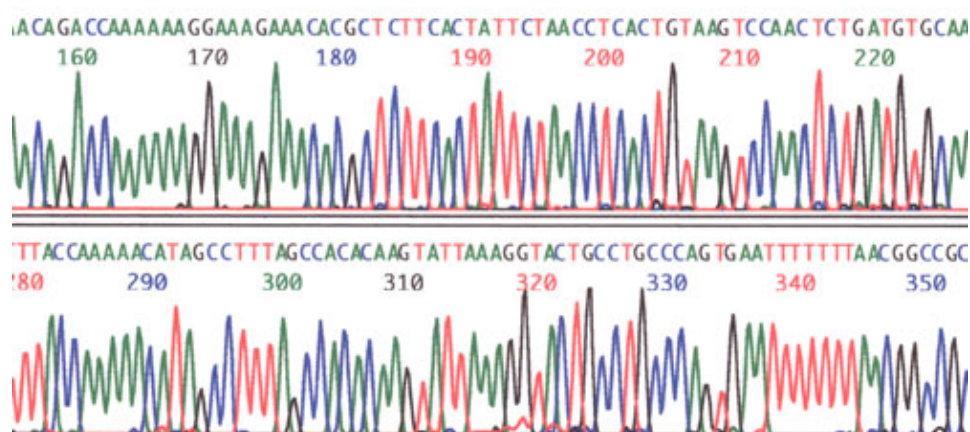
Several members of the focus group are involved with developing and/or curating internet databases of interest to the astrobiology community. The Marine Biological Laboratory (Mitch Sogin, Monica Riley) hosts several public databases, including GenProtEC (<http://genprotec.mbl.edu/>) which presents functional data for proteins of the eubacterium *E. coli*, and Microscope (http://microscope.mbl.edu/reflections/baypaul/microscope/general/page_01.htm), which contains images, classification schemes, and educational resources pertaining to microbes. The Paleobiology Database (<http://www.paleodb.org/>) is being developed by a consortium of paleontologists, including focus group member Charles Marshall (Harvard University) and includes collection-based occurrence and taxonomic data for marine and terrestrial animals and plants. Sudhir Kumar (Arizona State University) and Blair Hedges (Penn State University) are developing (with support from the National Science Foundation (NSF)) a database of molecular and fossil times of divergence, to be released later this year. Focus group members will continue development of databases of interest to the astrobiological community.

FOCUS GROUP DESCRIPTION & ACTIVITIES

The activities of the Evolutionary Genomics Focus Group during this past year began with a workshop ("special session") at the Gordon Research Conference on the Origin of Life at Bates College, Maine (13–18 July, 2003), chaired by Lake and Hedges. It was supported by workshop travel funds provided by NAI. In this workshop, 19 speakers were split into two sessions on separate days: "Origin and Evolution of Eukaryotes" (Beverly Green, Peter Gogarten, Herve Philippe, Maria Rivera, Jim Lake, Blair Hedges, Leonid Moroz, Lynn Rothschild, Hyman Hartman) and "Tree of Life and Horizontal Gene Transfer" (Joe Kirschvink, Yuri Wolf, Peter Gogarten, Herve Philippe, Richard Greenblatt, Jim Lake, Eugene Koonin, Joshua Rest, Blair Hedges, and Ford Doolittle). The importance of horizontal gene transfer in the early history of prokaryotes and eukaryotes provided a focal point of debate for both sessions.

Early in 2004, the focus group co-chairs submitted a proposal to NAI for renewal of the focus group, for an additional three years. The proposal was circulated among the NAI Executive Council and a presentation was made in-person to that group during the Astrobiology Science Conference held at Ames Research Center in March, 2004. The NAI Executive Council approved the proposal later that day and the co-chairs received final approval from the director of NAI.

The co-chairs have since discussed plans for future workshops. One workshop on molecular clocks has tentatively been set for May, 2006, at Arizona State University. It will be held in conjunction with the annual meeting of the Society for Molecular Biology and Evolution, hosted by Evogenomics Focus Group member Sudhir Kumar.



DNA sequence from a portion of a gene, as detected by a genetic analyzer, where the four colors represent the four constituent bases: adenine, cytosine, guanine, and thymine.

Highlights

- Focus group workshop at Origin-of-Life meeting: The Evolutionary Genomics Focus Group held a workshop at the Gordon Research Conference on the Origin of Life in July, 2003. The importance of horizontal gene transfer in the early history of prokaryotes and eukaryotes provided a focal point for debate.

Roadmap Objectives

- **Objective No. 4.1:** Earth's early biosphere
- **Objective No. 4.2:** Foundations of complex life
- **Objective No. 4.3:** Effects of extraterrestrial events upon the biosphere
- **Objective No. 5.1:** Environment-dependent, molecular evolution in microorganisms
- **Objective No. 6.2:** Adaptation and evolution of life beyond Earth
- **Objective No. 7.2:** Biosignatures to be sought in nearby planetary systems

Mission Involvement

<i>Mission Class*</i>	<i>Mission Name (for class 1 or 2) OR Concept (for class 3)</i>	<i>Type of Involvement**</i>
2	TPF	Background Research

* Mission Class: Select 1 of 3 Mission Class types below to classify your project:
 1. Now flying OR Funded & in development (e.g., Mars Odyssey, MER 2003, Kepler)
 2. Named mission under study / in development, but not yet funded (e.g., TPF, Mars Lander 2009)
 3. Long-lead future mission / societal issues (e.g., far-future Mars or Europa, biomarkers, life definition)

** Type of Involvement = Role / Relationship with Mission

Specify one (or more) of the following: PI, Co-I, Science Team member, planning support, data analysis, background research, instrument/payload development, research or analysis techniques, other (specify).

The work in this focus group provides background information for all NASA missions searching for life elsewhere. A better understanding of the early history of life on Earth, and evolution of the atmosphere (tied in many ways to the origin and evolution of microbes and other organisms), provides general biosignatures for life, as will be needed in interpretation of data from TPF (for example).